FINAL TECHNICAL REPORT – USGS COOPERATIVE AGREEMENT FOR SEISMIC NETWORK OPERATIONS

Cooperative Agreement No:	07HQAG0010 & 07HQAG0011	Project Start Date:	1 Feb 2007
Network Name:	Pacific Northwest Seismic Network		
Term Covered by This Report:	1 Feb 2007 - 31 Jan 2010		
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Summary of network, focus of operations, and main accomplishments

PNSN is the ANSS Tier 1 Regional Seismic Network monitoring seismicity and earthquake ground motions in the states of Washington and Oregon. ANSS supports PNSN with grants to the University of Washington, where the management and central data processing facility of PNSN are located, and the University of Oregon, where Dennis Fletcher maintains and operates southern PNSN stations and gathers data from the UO subnet. This Final Technical Report is meant to include the report from the UO subnet, which is found in its entirety in the "Operation Highlights" section below. Collaborating and coordinating in various ways with smaller regional networks within and surrounding the two states (Cascades Volcano Observatory, University of Oregon, US National Network, Pacific Northwest National Laboratory at Hanford, Pacific Geoscience Centre Canada, The Montana Bureau of Mines, and the Northern California Seismic Network), we are the authoritative regional source for seismic data and information products. We work in close cooperation with CVO to monitor activity of dangerous Cascade volcanoes, provide data in real-time to NOAA for tsunami monitoring, and help the Pacific Northwest National Labs and Battelle (Batelle/PNNL) produce seismic monitoring products for the DOE in the area of the Hanford Reservation site in eastern Washington. The 3-year cooperative agreement just completed was the first such with John Vidale and Paul Bodin having taken over complete responsibility of the network from Steve Malone.

As a broad-brush statement, we can say that the overall nature of data collection, processing, analysis and archival, ***in the production system***, has not fundamentally changed, and revisions in operation have been more evolutionary. This has been by design, to ensure continuity in our network coverage, catalog contributions, and other products. Additional seismic stations have been added to the network, and hardware and software upgrades have taken place in the production system, but the overall philosophy and design has remained in place. It is also a state of dynamic equilibrium, we change things carefully and slowly.

However, this surface continuity belies the fact that nearly two entire parallel networks have been put into place, and there has been a complete revamping of the hardware, networking, and software components (including physical re-arrangements of hardware) that drive the system in order to increase robustness, speed, and maintainability of the system as well as to prepare for future evolutions (now in progress!). We have not only replicated the current production processing system in fail-over mode at a second location, but we have established the AQMS (ANSS Quake Monitoring System) system in test mode, in preparation to switch to this system as the production one this calendar year. Also, at the moment we are engaged in a lot of activity renovating, and in numerous cases re-locating seismic stations for the ARRA-funded RSN seismic upgrades. Moreover, we are working hard to ensure not only that we meet the ANSS performance criteria, but that we can document this appropriately as well.

During the past three years we met with success obtaining funding from sources other than ANSS and the EHP of USGS. PNSN's other financial sources includes the state of Washington, the University of Washington, Battelle/PNNL for eastern Washington operations, and the City of Seattle to install and operate strong motion stations. Also we have received assistance from USGS Multihazard Demonstration Project funds to purchase field hardware, including some NetQuakes accelerographs that are in the process of being deployed (~30 installed, mostly in the Seattle metropolitan area, at present). Our state funding has been reduced because of state budget problems, and funding from NOAA via the CREST project seems to be stable now for a year or two, but was, during this performance period, rather choppy and difficult to plan for. We continue to pursue additional sources of support and seismic station acquisition. We have active development initiatives with IRIS, with U.S. Congressional representative Norm Dicks of Washington, with the US Department of Energy through the Hanford site Mission Support Alliance team, and with the NSF Earthscope's Cascadia Amphibious Facility project.

Work performed during the 3-year award period.

Management/Personnel restructuring

Major personnel restructuring has taken place beyond the passing of the management baton at PNSN. Much of this has been funded only in part by ANSS, and has been allowed by new partnerships with the State of Washington. Major PNSN personnel additions are:

- Computer Systems Manager, Terry Bartlett.
- Electronics Technician, Bethaney Dukellis.
- Field technician, Jon Connolly
- 0.7 FTE Research Scientist, Dr. Renate Hartog
- Field techician Montee Gillespie (ARRA funding, VHP+EHP)
- Research Scientist Dr. Silvio De Angelis (ARRA funding, VHP+EHP)
- 1.0 FTE Senior Computer Specialist, Dr. Victor Kress

PNSN personnel departures were:

- Electronic Technician, Mike Archbold (did not work out, replaced by B. Dukellis)
- Research Scientist, Ruth Ludwin.
- 0.5 FTE senior computer specialist Bill Gustafson
- Jon Connolly (started own software company!)
- Wes Thelen (started USGS Mendenhall postdoc at CVO)

These changes have left PNSN more prepared to implement the hardware and software requirements of the new AQMS system.

Operational Highlights

A quick summary of the scope and scale of PNSN seismic operations can be gleaned from Figure 1, which provides a map of PNSN stations, and from Table 1, which summarizes network seismic data contributions.

The past three years have seen enormous changes in the quantity of data arriving in the network, both increases and decreases. It is a remarkable testament to the PNSN staff and the data management system that they have constructed that the system has been able to deal rapidly with addition of so many data imports, to use them for locations and magnitudes and the generation of other seismological data products, and then to deal rapidly with many of them leaving again as well.

Much of the reason for the data "turnover" is associated with the NSF-funded EarthScope project's Transportable Array (TA) and Plate Boundary Observatory (PBO) stations. The start of this 3-year Cooperative Agreement essentially coincided with the arrival of the full TA deployment in the PacNW. High-quality broadband data were acquired by our earthworm system (via the Bud server at IRIS DMC) for 90 regional sites. By the final year of this Cooperative Agreement, most of these had been decommissioned and removed. We had been able to secure private funding (from the Murdock Foundation Trust, the state of Oregon Department of Geology and Minerals Industries, and Batelle/PNNL) to purchase the vaults and hardware for 21 of these sites, which remain permanently in the region. Most of the 21 stations will be augmented with 3 additional channels of strong motion data. TA station data acquired into the PNSN data stream is helping us to automatically produce moment tensors, to calibrate Ml, and to better characterize seismicity, particularly east of the Cascades. We now also acquire data from boreholes (~600 ft deep) triaxial short-period seismometers at ~20 stations (60 channels) of the Plate Boundary Observatory (PB network).

Then in the last few months of this Cooperative Agreement the TA began re-deploying sites for a special "amphibious" (onshore/offshore) experiment, the Cascadia Amphibious Facility (CAF) An additional 13 broadband stations are back in the region, with as many as 25 to be installed by the end of summer, 2010. The geometry of the CAF was worked out carefully with PNSN, cognizant of the regional broadband upgrades we are now carrying out with ARRA funding. We hope to be able to find funding to retain as many as possible of these re-deployed TA-style stations, as we were able to do with the Murdock Trust. These new permanent and semi-permanent regional data sources help to provide monitoring redundancy and/or augment station coverage. Moreover, we are continuing to acquire new seismic datastreams from our CVO partners (CC network), including better coverage of the central Oregon cascades (Three Sisters volcano), Mt. St. Helens, and Mt. Rainier.

Some specific operational notes include:

- New PNSN stations (UW network): LKVW, Lakeview, Oregon 4-channels (3D SMO + SPZ), MNWA, Manchester, Washington (3D Strong Motion), WEL1 & WEL2, Wells dam in eastern Washington (3D SMO), MAUP, in Maupin, Oregon (3D SMO), NEWO, in Newport, Oregon (3D SMO), and SEAS in Seaside, Oregon (3D SMO). Also CDMR is a free-field SMO site funded by the City of Seattle to monitor landslide hazard and dam safety near one of the cities two main drinking water reservoirs. Working with CVO, we established 3 new regional sites that are generally good sites but have special importance for monitoring regional volcano seismic activity, these include STAR (a 3-component short period site at 11,000 feet in elevation, the highest seismic site in the continental US, on the shoulder of Mt. Rainier), OBSR (a wide-band site on the north flack of OBSR), SHUK (a wide-band site near Mt. Baker). The final site established during this Cooperative Agreement was LRIV (ARRA upgrade of CREST-funded stations OPC deployed in a former TA vault).
- We have taken over the operation and maintenance of 18 former TA stations. The data flow has been re-routed to go directly through UW with all of our other data channels. Our first full year of sole operation of these stations has not been without frustration or miscues. We have learned that the TA vault deployment strategy is not optimal for operation of permanent seismic stations in the damp PacNW west of the Cascade Range. Repeated opening of the vault lid, we suspect, increases the chances of inundation, and the site design is such that water tends to be retained around the sensor, and humidity affects the electronics which are placed in the vault. Moreover, insufficient power leads to periodic station outages during difficult winter months. The sites generally have good seismic noise characteristics, however. We are redesigning a number of sites to place the electronics in an enclosure external to the sensor vault, to change the material into which the sensor is packed to pea-gravel to reduce the water retention around it if and when flooding does occur, and to add solar power generating capacity and battery storage.
- We currently have deployed about 30 NetQuakes accelerographs, 28 of which are in the metropolitan Seattle area. Our design is that the data from these triggered systems can be incorporated into our automatic processing. However because of latencies, most the data they have produced (and there have been but a few smallish earthquakes since their deployment) has usually been used in reviewed, and second-generation, products.
- Duty Seismologist rotation and procedure formalized. This procedure ensures that a trained seismologist is able to respond to any “alert” earthquake (basically $M > 3$), review data, and notify NEIC and emergency managers.
- SMO data archived at IRIS DMC. Every channel of continuous UW network data is now archived continuously and in near real time at the IRIS DMC. This not only provides rapid access to UW data to external users, but permits us to use the IRIS DMC’s broad range of data quality analysis mechanisms. We do not yet archive our NetQuakes triggered data at the main waveform archive, although there is nothing in principal that stops us from doing this; we simply wish to have a better understanding of how these instruments work. The waveforms are archived in our AQMS system.
- NSMP data added to ShakeMap automatic processing. We now access waveforms from USGS NSMP free-field sites (all dial-up). These are probably not included in our automatic shakemap, but are included in subsequent, reviewed, shakemaps.
- Working with NSMP to archive SMO event data. We are developing a way to add strong motion data from the UW network into the NSMP/CDMG archives quickly. The plan is that NSMP will

take data from our waveservers when certain trigger criteria are met. The status is that NSMP is inputting our station metadata into their database. This is still a process that is largely untested.

- Automatic Moment Tensor computation instituted. For all alert events we now attempt moment tensor computation automatically. This solution is not "released", but reviewed solutions will be posted to our "special events" webpages that are automatically generated following important earthquakes in the region. Our experience to date has been mixed. Most alert events were too small to have enough low-frequency energy to get good stable solutions. The large events have been offshore, outside of our authoritative region, and in an area where our Greens function catalog is not very good. NEIC produced results for these before we were happy with ours!
- Computers have been "hardened" and many new servers installed. We have lashed down our 3 computer racks, and instituted regular testing of the emergency backup power generator. We have our analysis software running on 2 replicate Sun computers. This "payed off" for us when one of the computers failed, yet we were able to continue operating without loss. However, a third computer became the backup, and that had been our "development" system. We have switched out all of our old import computers, and upgraded to Earthworm 7.3 acquisition, converting all data to SCNL, with location codes. The import computers are now running Linux, which gimes us a bit more cost-effective way of importing data.
- We have replaced the old QDDS system with EIDS.
- Reporting boundaries changed. We've expanded and simplified the boundaries for which PNSN is "authoritative" in EIDS to basically include the entire states of Washington and Oregon.
- We have rebuilt our analog telemetry rack. This work was delayed by extra fieldwork occasioned by strong storms in the winter of '06-07. At the same time we replaced our old discriminator cards with much more stable modern version. This will improve robustness and has improved signal / noise ratios.
- ANSS regional committees reconstituted. Left to languish for several years, we have activated and engaged our Regional Advisory Committee to help guide our development. The RAC has been very active and annual meetings provide good opportunities for our regional clients to see what we are up to, and to give advice. We have re-activated also the Strong Motion Siting committee who have been advising with detailed requests and advice for where to target NetQuakes roll-outs.
- Coordination with regional network partners, and clients has been a major effort of the PNSN during this Coop Agreement period. Our frequent contacts include:
    - CVO
    - PNNL
    - BPA
    - UW
    - State and Regional EMA
    - Academic engineers
    - IRIS / NSF / PBO
- Shakemap. The ShakeMap suite of products is a large effort at PNSN. We have spent tremendous effort not only to run and test ShakeMap, but have added numerous enhancements, and are working to employ the best attenuation relationships we can, and to demonstrate that they are producing accurate results.
    - Produced high resolution Urban maps. At the request of regional EMAs, we developed ShakeMaps calculated at about 220 m grid spacing, relying on dense geologic control.
    - Rationalizing/Testing. Making sure our maps are accurate is critical we are working to test, and improve:
        - Site Corrections
        - Attenuation Relations
        - Delivery mechanimes

- SoundShake08 was a Puget Sound region earthquake disaster planning exercise that tood place in March ’08. We worked closely with City, County, and State EMAs to provide realistic scenarios (shakemaps included) for the exercise.

- High Mountain sites visited/rebuilt: GPW, RCS, RCM, RVC, FMW, LADD, OSD.
- YEL removed. This station which had operated on Mt. St. Helens for years was consumed, finally, in 2007 by a glacier. An emotional farewell.
- GPS data investigations. We have been working with Gavin Schrock of the City of Seattle, and who runs the regional surveyors GPS network, to provide real-time 1-sec GPS positions for sites as a prototype for how to include realtime GPS (RTGPS) data in PNSN network. We have augmented this with 1-sec GPS positions provided by Tim Melbourne at Central Washington University. The precision of these observations is low (~2.5 cm), however they will be extremely useful to rule out, or characterize, large earthquake sources.
- REQ2. http://www.pnsn.org/req2/
- Better Webicorders. http://www.pnsn.org/WEBICORDER/BETTER/pnsn_staweb/index.html
- Tremor locations. http://www.pnsn.org/tremor/

University of Oregon Cooperative Agreement

The University of Oregon, through USGS external grant award number 07HQAG0010 has cooperatively operated PNSN’s southern Oregon analog, broadband, and strong motion stations from 2/1/2007 through 1/31/2010. The UO reports:

- UO has continued the cooperative efforts with UW. These two units are effectively jointly managed by the PNSN with regular (biweekly) coordination meetings, and frequent joint field expeditions.
- UO maintains and operates several short period and broadband seismograph stations in southern Oregon and, through Earthworm data acquisition systems, supply UW and other repositories with data from several of these stations.
- UO repairs of non operational sites takes priority over all other tasks and if a site visit is required for further investigation it should occur within 24 hrs if access to the site is possible. Repairs are then scheduled as weather permits and repair parts are available.
- Problems with data quality are pursued using the same urgency but second in priority. Site upgrades and maintenance are completed as time allows.
- Routine maintenance has been performed on 24sites as scheduled.
- Repairs have been made at 22 sites. These tasks have required 105 trips with a total of 20,847 miles.
- All data is passed directly to UW.
- From February 1, 2007 to January 31, 2010 $269,487.00 total funds were expended.

Interesting Earthquakes and A Smattering of Science

• *Maupin Earthquake Swarm.* Starting in January 2007, a series of earthquakes, ultimately numbering in the hundreds, initiated near the north central Oregon community of Maupin. The largest earthquake was an M4.2, but activity continues at smaller magnitudes and reduced rates to the present. The Maupin swarm was close to the site of one of the larger instrumental earthquakes in Oregon in the 1970s. (M5.6). PNSN responded to local citizens and state agencies inquiries by deploying our portable seismic array to better characterize the source. The study revealed a very tightly-clustered series of earthquakes with nearly identical waveforms (more precisely 2-3 families). A remarkable feature of these http://www.pnsn.org/NEWS/PRESS_RELEASES/maupin/ and Braunmiller et al: earthquakes that separates them from most continental swarms, is their rather deep origin: 17.5-18 km., very well constrained by data from the portable deployment.
http://www.earthscope.org/es_doc/highlights/maupin_14jul08.pdf

• *Richland (Hanford) Earthquake Swarm.* Starting in January, 2009, a series of earthquakes ultimately numbering in the hundreds, initiated near the south central Washington community of Richland, on the

Hanford reservation site. The largest of these was an M3.5, but because of their proximity to the TriCities, many have been strongly felt. Again responding to concerns by local citizens and because of their proximity to Washington's largest nuclear power generating station, we worked with our PNNL colleagues to incoporate data in realtime from a small temporary portable deployment. In stark contrast to the Maupin swarm (although not in dissimilar geologic settings) the Richland swarm events are extremely shallow (<1 km) showing a diversity of waveforms and focal mechanisms, and locations are variable and migrate systematically with time. Thanks to work by USGS deformation specialist, Chuck Wicks InSAR analysis revealed simultaneous surface deformation that has enabled us to image two faults, slip on which seems to be driving (or at least associated with) the earthquakes. Analysis of the swarm is still underway.

- *Cowlitz earthquakes.* An M4.5 near Mt. Rainier was examined in detail and a short paper prepared.
    - Hartog, R., J. Gomberg, S. Moran, A. Wright, K. Meagher, The October 8, 2006 M4.5 Cowlitz Chimney earthquake in Mount Rainier National Park, Seismological Research Letters, v. 79, p. 186-193.
- ShakeMap. Continuing implementation, testing, and planned use in regional exercises.
- Tremor. A wide variety of tremor studies are complete or underway, these are now yielding both scientific and practical results. Several relevant papers and numerous meeting abstracts and invited talks on this topic, including.
    - Rubinstein, J.L., J. Gomberg, J.E. Vidale, A.G. Wech, H. Kao, K.C. Creager, G. Rogers (2009), Seismic Wave Triggering of Non-Volcanic Tremor, ETS, and Earthquakes on Vancouver Island, *JGR*, vol. 114, B00A01, doi:10.1029/2008JB005875.
    - Peng, Z., J.E. Vidale., K.C. Creager, J.L. Rubinstein , J. Gomberg, and P.Bodin, Strong tremor near Parkfield, CA excited by the 2002 Denali earthqauke , *GRL* , vol. 35, L23305, doi:10.1029/2008GL036080.
    - Rubinstein, J.L. , M. La Rocca, J.E. Vidale, K.C. Creager, A.G. Wech (2008), Tidal Modulation of Non-Volcanic Tremor, *Science* , v319, pp. 186-189.
    - J. Gomberg, J.L. Rubinstein, Z. Peng, K.C. Creager, J.E. Vidale (2008), Widespread Triggering of Non-Volcanic Tremor in California, *Science* , v. 319, pp. 173.
    - Rubinstein, J.L., J.E. Vidale, J. Gomberg, P. Bodin, K.C. Creager, S. Malone (2007), Non-Volcanic Tremor Driven by Large Transient Shear Stresses, *Nature* , vol 448, pp 579-582.
    - Rubinstein, J.L., M. La Rocca, J.E. Vidale, K.C. Creager, A.G. Wech (2007), Tidal Modulation of Non-Volcanic Tremor, Science Express, published online Nov 22..
    - Gomberg, J., J.L. Rubinstein, Z. Peng, K.C. Creager, J.E. Vidale (2007), Widespread Triggering of Non-Volcanic Tremor in California, Science Express, published online Nov 22.
    - Rubinstein, J. L., J.E. Vidale, J. Gomberg, P. Bodin, K.C. Creager, S. Malone (2007), Non-Volcanic Tremor Driven by Large Transient Shear Stresses, Nature , vol 448, pp 579-582.
- Building monitoring. With experiments with our new portable instruments and examination of recordings from Olympia and California, we are exploring whether much more widespread instrumentation of structures in the Pacific Northwest is feasible and warranted. A manuscript is in draft form:
    - Bodin, P., J. E. Vidale, and T. Walsh, (in preparation). Damage transients and stiffness reduction during repeated strong shaking in the Washington Natural Resources Building, Olympia, Washington.
- Sensor Non-linearities. We have documented limitations in the fidelity of broadband sensors during motions heretofore thought to be accurately recorded. IRIS and Kinemetics personnel are examing whether instrumentation and siting details can be improved to mitigate such limitations.
    - Delorey, A., J. Vidale, J. Steim, P. Bodin, 2008, Broadband Sensor non-linearity during moderate shaking. Bulletin of the Seismological Society of America, Vol. 98, No. 3.

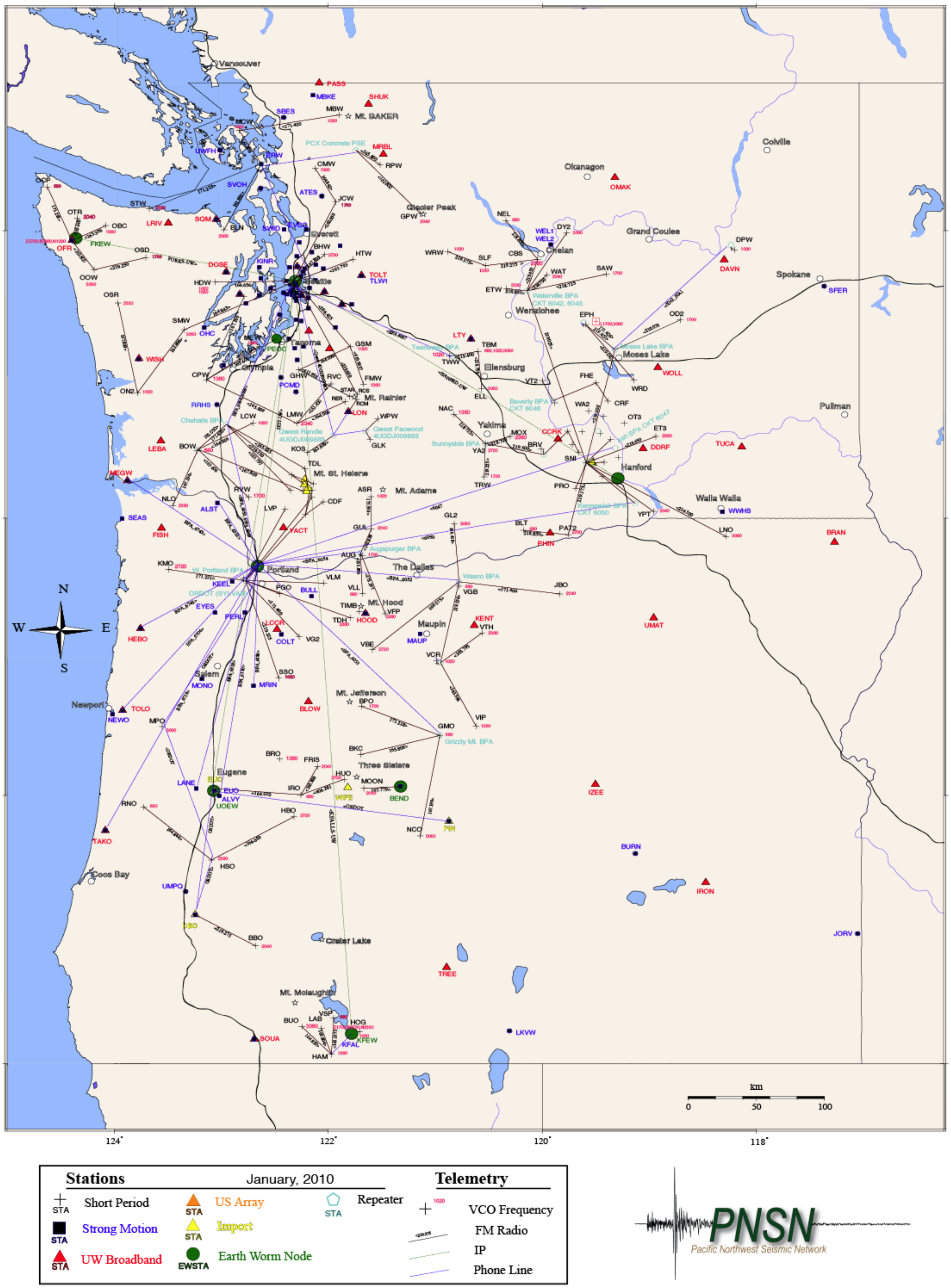

Figure 1. *Map of UW Seismic Stations and major telemetry paths. A more readable version of this map is available at http://earthweb.ess.washington.edu/~bodin/ANSS/PNSN Only Sites.eps. Lists of the UO and UW stations, and all station metadata, are available at: http://www.iris.edu/gmap/UO?timewindow=2010-2500 and http://www.iris.edu/mda/UW?timewindow=2010-2500 (respectively)*

Data Management Practices

PNSN is committed to meeting, if not exceeding, ANSS data management practices, and all of the ANSS RSN performance requirements. Of course, the backdrop for this is that the National Implementation Committee of ANSS has just adopted metrics aimed at documenting each network's performance to be measured against the adopted standards. We are currently working to devise policies and procedures to provide these metrics in a standard and automated way. The specific performance requirements for Data Management Practices include the following:

#	Criterion	standard
4.1	Waveform Availability Timeliness	30 60 Sec.
4.2	Amplitude Availability Timeliness	30 60 Sec.
4.3	Phase Picks Availability Timeliness	30 60 Sec.
5.1	Availability of Waveforms to External Users	60 Min.
5.2	Availability of Event Bulletin (parametric data)	60 120 Min.

We are making strong progress towards meeting the ANSS data management performance standards. Thanks to the early adoption of the EarthWorm data acquisition system, and the way we archive data, the system easily exceeds these standards in normal operation. As noted above, data from all of our stations apart from the NetQuakes stations is real-time and continuous. Data from legacy short period stations are transmitted as analog signals through a tangle of licensed-band FM radio and/or donated microwave carrier telemetry (see Fig. 1) and are digitized at UW (a few at remote nodes) as EarthWorm TraceBuf2 packets and placed on a shared network line. Data from digital stations (the bulk of the network) including SMO and BB stations and those SP channels digitized at remote nodes arrive via a variety of transport mechanisms (i.e., Internet, leased line/modem, VSAT, CDMA) and are imported to EarthWorm by specialized import computer servers, with the resulting TraceBuf2 packets also placed on EarthWorm "rings" on the private network line. Our EarthWorm processing machines pick up these packets and process them in a standard automatic EarthWorm system triggering on subnets, phase picking, and automatically locating earthquakes where possible. To be more accurate and detailed, currently two duplicate systems that produce, ultimately, data products in a special "UW" format using a special UW data format and location algorithm, and two other duplicate systems that produce data products using AQMS in a standard AQMS database are all using data on the private line. The results of these processes are packets that are placed in rings on the private network line (only one server, the "master", at any given time does alarming and notifications and triggers further product processing). Waveform data are placed, still in near-real-time, into EarthWorm WaveServerV wavetanks and in Winston Wave Server (WWS) tanks. Only NEIC has access, through a special router, to the private network from outside of UW, and thus can see all of not only our raw data in realtime, but also the picks, amplitudes, and automatic hypocenters as soon as they are calculated. EarthWorm exports provide exported waveforms (and picks and parametric information if desired) onto public-facing network lines to be shared with collaborative partners at surrounding and cooperating networks, and through other lease-line telemetry to the Alaska and Pacific Tsunami Warning Centers. Data from all continuous real-time channels is provided to the IRIS DMC, which is PNSN's waveform archive, where they are made available to any user worldwide. Event bulletin information for all locations meeting certain quality criteria are reported directly to EIDS and thus to the ANSS US Earthquakes catalog as soon as they are calculated.

In summary, latencies for waveforms, picks, and amplitudes at the UW data processing facilities is on the order of a few seconds from their arrival at UW or their generation within our processing systems. Certain users (notable NEIC) have absolutely immediate access to the raw and lowest-level processed information (phase picks and amplitudes). Certain users have a few tens of milliseconds of delay to access these. The waveforms with full metadata are available to the general public from our archive within minutes (see Fig. 2 for an illustrative example). Automatic parametric (bulletin) data are available within moments of their production, which is generally a couple of minutes for small earthquakes, but may be more that 5 minutes for big earthquakes, because we wait for more data before processing larger events. We do not yet share phase picks with the wide world, but only by special arrangement.

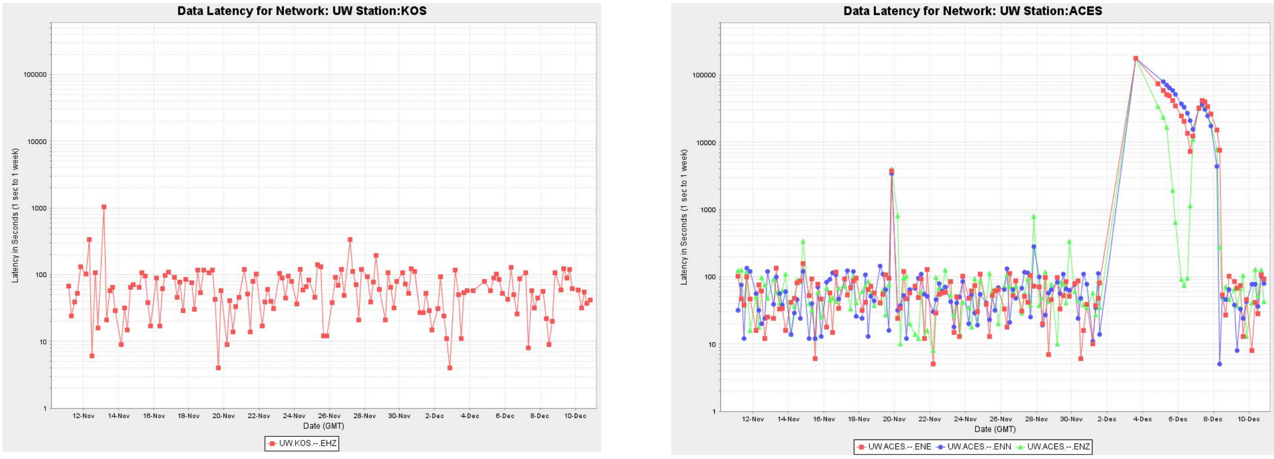

Figure 2. Latencies for two representative UW seismic stations, as reported by the IRIS DMC archive. These latencies represent, in general, the time when waveforms with full metadata are available to the world. Typical latencies are 2 minutes are less, but problems with the station or telemetry (as for station ACES on the right side) can induce much longer outages. We are working to automate the presentation of such metrics for all ~500 channels we archive with the DMC.

By far the greatest delays are due to latencies receiving data from stations. This has been a particular problem with data from contributing networks, particularly PBO, TA, and USNSN stations. The mission of these research networks is usually tilted toward maximum data recovery rather than minimal latency, and the data acquisition schemes of these networks often creates latencies arriving at UW of 10s of seconds (and sometimes hours!). Figure 3 shows an example of the latencies of data availability from our IRIS DMC archive. From such "typical" plots, we can generalize that, when stations are operating normally, UW network waveforms are available to external users in between 1 and 2 minutes from time stamp. Interestingly, this is essentially instantaneous from the perspective of most external users, who presumably would be interested in waveforms from events we report into EIDS. This reporting (i.e. performance standard 5.3) may be delayed relative to the waveform delivery, because we report locations from the program 'Spong', using regional velocity models on a triggered "event gather" in UW format, and automatic coda magnitude estimates. These have been generated, according to a recent non-statistically-robust survey of QDM logs, in 2-5 minutes. Time variation is due, probably, to the duration of the trigger (and hence size of the earthquake). In no case will the trigger duration exceed 5 minutes. For any earthquake exceeding Md 2.9, we have an on-call seismologist with the target of reviewing the traces, relocating and recomputing magnitudes (automatic Ml is calculated for every event Mc>2.9, too) within 10 minutes. We have been producing these in more like 15 minutes for several recent "alert" events.

We remain the most challenged by the reportage of phase picks (standard 4.3), which are not currently reported anywhere as they are made in UW format, in event-related "pick files". They are made available to researchers upon request. We intend to implement the availability of these when we convert finally to AQMS as our production system.

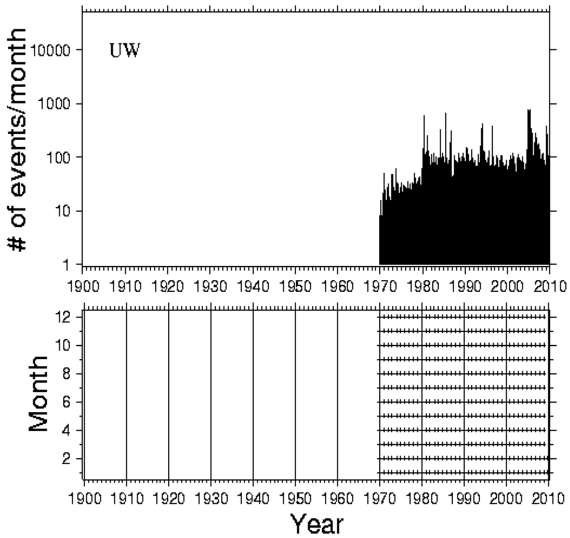

Figure 3. Contributions from the PNSN to the ANSS ad hoc composite catalog. Most current version available at:

http://www.ncedc.org/anss/inventory/UW.inventory.gif

Figure 3 illustrates the status of PNSN catalog contributions. We report automatically generated event parametric data that meets certain quality criteria to the EIDS system, including not only earthquake hypocenters and magnitudes and origin times, but also add-ons like ShakeMaps, and Moment Tensors. These submissions are revised upon human review of the data, generally several times daily (although weekends we sometimes do not review as frequently). We submit our catalog to the an hoc ANSS catalog automatically every day, and have done so for years.

The IRIS DMC also provides usage statistics for requests for data from the community, by subnet. Our network data are well-used. An example included below, shows the usage of just the UW subnet data for the quarter including October through December, 2009. In this quarter, for example some 1.3 million waveforms of UW network code data were delivered to researchers worldwide.

Name	INSTITUTION	#_reqs	#_kbytes	#_seismograms
Ali	forautodrm@gmail.com	37	73306	1314
WHC	wangustc@mail.ustc.edu.cn	54	78271	724
Jenny	jenny.hanna@yale.edu	8	1823652	9498
O126W	upv22@mst.edu	2	1096463	12327
P126W	upv22@mst.edu	8	2285973	26886
Q126W	upv22@mst.edu	2	941711	14700
pardo	pardo@ipgp.fr	6	35026	40
OSUrmt	jbraunmi@coas.oregonstate.edu	21	30108	1187
OSUrmt	rroberts@coas.oregonstate.edu	7	21159	696
TA_GMA	manoch@iris.washington.edu	124	107990	2676
Aus_NDC	aus_ndc@ga.gov.au	994	72271	2987
Chen_Ji	ji@geol.ucsb.edu	1	1020	116
Qin_Cao	qinc@mit.edu	7	288447	2155
Yu_Chen	yuchen@ic.sunysb.edu	2	17628	66
Yu_Chen	yuchen@mantle.geo.sunysb.edu	1	8814	33
unknown	yuchen@ic.sunysb.edu	1	8814	33
Ben_Kohl	kohlb@saic.com	1	1411	9
SOKOLOVA	sokolova@kndc.kz	44	99344	4804
Tao_Wang	wang1311@umn.edu	9	233878	4710
Yike_Liu	ykliumail@yahoo.com	7	20113	447
ktwalker	walker@ucsd.edu	1	63818	96
woodward	woodward@iris.edu	53	28357	3030
Yang_Shen	yshen@gso.uri.edu	153	166420549	269941
Brad_Woods	bbwoods@geology.cwu.edu	4	77587	36
David_James	james@dtm.ciw.edu	8	55179	2972
Haiying_Gao	hgao@uoregon.edu	850	32959711	118018
John_Vidale	vidale@uw.edu	1	18724	29
Marian_Ivan	marian.ivan@g.unibuc.ro	4	3729	49
Ralf_Hansen	rhansen@eos.ubc.ca	2	444441	8473
Satoshi_Ide	seis@eps.s.u-tokyo.ac.jp	369	26708487	56750
SeungguRhee	sgrhee@yonsei.ac.kr	1	120	10
Ahmet_Okeler	okelerah@gmail.com	34	352350	1992
Anna_Makinen	amm210@cam.ac.uk	5	9194	32
Jamie_Barron	jaab3@cam.ac.uk	28	82341358	311483
Tobias_Diehl	tdiehl@ldeo.columbia.edu	2	23326	1391
Amir_Farahbod	amirf@sfu.ca	145	464313	1347
Juan_Benjumea	juan@isc.ac.uk	935	949878	32160

Kate_Allstadt	allstadt@uw.edu	2	502091	403
Kate_Allstadt	allstadt.k@gmail.com	2	140880	61
Mark_Williams	mwilliams@coas.oregonstate.edu	114	1283757	470
MikeCleveland	kmc388@psu.edu	1	1140	126
Renate_Hartog	jrhartog@gmail.com	1	110941	101
Tomoya_Harada	haratomo@eri.u-tokyo.ac.jp	1	1680	140
Weston_Thelen	thelenwes@gmail.com	1	6500	40
Sara_Dougherty	sarad@gps.caltech.edu	7	19069	225
Gene_A_Ichinose	forloop@bellsouth.net	2	877	6
Genevieve_Roult	groult@ipgp.jussieu.fr	2	7360	190
Mike_Brudzinski	brudzimr@muohio.edu	2987	30018902	38834
Mohammad_Raeesi	raeesi@geo.uib.no	8	23316	1540
roger_denlinger	roger@usgs.gov	7	16902	41
Ali_Seismologist	forautodrm@gmail.com	2	160	2
Brandon_Schmandt	bschmand@uoregon.edu	1	79759	3421
Nicholas_Schmerr	nschmerr@dtm.ciw.edu	6	19696	141
ArchiveDataCenter	nobody@iris.washington.edu	13	58766	886
Justin_Rubinstein	jl.rubinstein@gmail.com	1	31632	14
Kaneshima_Satoshi	kane@geo.kyushu-u.ac.jp	32	400106	5104
SPAGNOTTO_SILVANA	pampa113@gmail.com	1	96	12
Garrett_Gene_Euler	ggeuler@seismo.wustl.edu	49	454608	3739
Michael_Brudzinski	brudzimr@muohio.edu	1899	400439740	392299
Jackie_Caplan-Auerbach	jackie@geol.wwu.edu	4	2086611	971
Helena_Dominguez_Moreno	helenadm_87@hotmail.com	1	3072	54
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TOTAL		9075	753874181	1342037

Continuity of Operations and Response Planning

We divide our planning into 2 phases, true "continuity of operations" planning where we must respond to smaller, more contained, problems and "contingency plans" which we consider a regional disaster that basically threatens to take the network completely down. Examples of the first include compute hardware failure, power failure, telemetry failures, earthquake swarms, etc. Occurrences needing contingency considerations are those that will probably affect the entire region and/or our networks staff abilities to get to work etc. Examples might be a massive earthquake, epidemic, or attack. Our contingency planning lags, so we will not discuss it further in this report.

We are making progress towards the continuity of operations part, but have formalized them only in draft form as of this writing. They are being prepared in collaboration with the USGS EHP Seattle field office at the UW. We have redundant computer systems that operate in fail-over mode. We have hardened our computer racks and telemetry racks with lash-downs. We have sought, and recently received, several thousand dollars in grants from the University of Washington for non-structural earthquake hazards mitigation which we are using in part to base-isolate our computer racks. We have two separate power circuits in our data room that are on UPS for short outages, and have a large diesel-powered generator for longer outages. We have instituted a quarterly testing of the generator, with annual servicing from professional mechanics. We have identified a vulnerable "single point of failure" computer network switch at the University, and have been working with the UW Computers and Communication group to institute an automatic fail-over.
protocol to build redundant paths. This has been implemented and recently tested. The public hits a high-volume website that is separate from our internal website...we generate content locally under low load, and the local content is rsynched to the high-volume site maintained by the university. We have purchased and deployed terminal servers so that in the event we are unable to make it to work, our computer system administration can be done remotely. Likewise, our manual review and analysis products can all be generated remotely by lab personnel. We have arranged, and actually used, a telephone conference line for coordination after an alert earthquake any time of day.

We are following ANSS lead in using the soon-to-be set-up web reporting of Continuity of Operations information.

Metadata Availability

PNSN is committed to "getting our metadata right". We currently produce dataless seed via PDCC for all channels that are archived in near-realtime (all UW network SCNs collected, basically) at the IRIS DMC. There are occasional discrepancies that we discover and repair, but we are really up to date with the current data. Legacy triggered event data are not necessarily up to date. There is a "hole" in the archived triggered data for years 1999 – 2002, largely because the metadata for this period is not up to par. Correcting this has been a lower priority for PNSN.

Our channel response information is available from the IRIS DMC. It has not been a priority for us to keep a separate metadata cache. That said, we are following progress in the "station XML" development, and plan to be compliant with the agreed-upon standard.

Station metadata will also be entered in to the ANSS web-based reporting mechanism when that is deemed ready for usage.

One caveat is that we have been challenged to get our data into the NSMP/CDMG "strongmotioncenter.org" strong motion data center website. In working with USGS staff, we determined that it was easier for them to obtain our station metadata (for strong motion stations only) from raw webpages on the UW website, and to manually enter it. This process has been slow, but the goal is that for a strong motion event (PNSN's choice of threshold), the strong motion data center will hit our waveservers and be able to generate and deliver data products of engineering interest quickly (as was done for recent California earthquakes).

Table 1. Summary Statistics for Regional/Urban Seismic Network (as of 31 Jan. 2010)

Total no. of stations operated and/or recorded	**310**
Total no. of channels recorded	**727**
Reported to IRIS DMC in 2007	**655**
No. of short-period (SP) stations	**156**
No. of short-period (SP) stations with metadata	**151**
No. of broadband (BB) stations	**51**
No. of broadband (BB) stations with metadata	**51**
No. of strong-motion (SM) stations	**133**
No. of strong-motion (SM) stations with metadata	**133**
No. of stations maintained & operated by network	**As above**
-same, with full metadata	**As above**
No. of stations maintained & operated as part of ANSS	**As above**
-same, with full metadata	**As above**
Total data volume archived (mbytes/day)	**~24,500**

Table 2. Earthquake Data and Information Products

Network Products		
Does the network provide the following?	**Yes/No**	**Comments/Explanation**
Primary EQ Parameters		
Picks	No	Produced internally, distribute upon request.
Hypocenters	Yes	Reported to EIDS
Magnitudes (& Amplitudes)	Yes	Mcoda, Ml, Mw (report best..usually Mc)
Focal mechanisms	Yes	1st Motion
Moment Tensor(s)	Yes	Automatic attempt for all ShakeMap events
Other EQ Parameters/Products		
ShakeMap	Yes	Standard and "high" resolution M3.5 + or felt
Finite Fault	No	
Supplemental Information		
Felt Reports	No	Rely on CIIM
Event Summary	Yes	For felt events or M>~3 events
Tectonic Summary	Yes	But not automatically....we are working on it.
Collated Maps	No	Working on it
Refined Hypocenters (e.g. double-difference)	No	
Web Content		
Recent EQ Maps	Yes	
Station Helicorder	Yes	
Station noise PDFs	No	Available through IRIS DMC, we now produce them internally for operational reasons
Station Performance Metrics	No	Again, all available through IRIS DMC
Network Description	Yes	
Station List	Yes	We prefer IRIS DMC (i.e. iris.edu/mda)
Station Metadata	Some	Strong motion stations...but it's really difficult to find! See above

Network Products		
Does the network provide the following?	**Yes/No**	**Comments/Explanation**
Email Notification Services	Not really	We notify certain clients (EMAs, for example), but refer most to ENS
Contact Info	Yes	
Region-specific FAQs	Yes	
Region-specific EQ info	Yes	Needs updating
Waveforms		
Triggered	Yes	
Continuous	Yes	
Processed	No	Should be handled by NSMEDC
Summary Products		
Catalogs	Yes/No	Only for E. Washington, for Batelle/DOE
Metadata		
Instrument Response	Yes	
Site Info (e.g. surface geology, Vs30)	No	Still trying to work out best way of doing this.

Descriptions:

Tectonic Summary: **Text and/or figures describing the tectonic setting of the event and related activity**

Event Summary: **Text and/or figures (press releases, collated media/disaster agencies info) that describes the earthquake and its effects**

Collated Maps: **Any map or set of maps that illustrates the event properties, tectonics, hazards, etc**

Processed Waveforms: **Specialized processing that is required by some portion of the community, e.g. processed strong motion records for the engineering community**

Catalogs: **Lists of parameters that describe an earthquake(s) or information used to describe an earthquake (e.q., picks, locations, amps,..)**

Region-specific earthquake information: **Description (text and/or maps) of historical earthquakes, faults/geology, etc.**